

THE DEVELOPMENT OF A SOFTWARE INTEGRATION TOOL FOR WATERSHED STUDIES – THE HYDROLOGIC ENGINEERING CENTER'S WATERSHED ANALYSIS TOOL (HEC-WAT)

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Abstract The U.S. Army Corps of Engineers along with its partners and stakeholders are conducting watershed and water resources management studies. These studies require a great amount of collaboration and coordination. Given that the study team includes members from many disciplines and sometimes separate offices, it is particularly difficult to coordinate and manage the development of the data, files, software, and alternatives to be evaluated. In many cases, hydrologic, hydraulic, economic, environmental, and social impact analyses are performed independently and the reporting and visualization of modeling results is not coordinated.

The Corps' Hydrologic Engineering Center (HEC) is developing an interface called the Watershed Analysis Tool (HEC-WAT or the WAT) to address these needs. It is designed to streamline and integrate a watershed or water resources management study using software commonly applied by multi-disciplinary teams. The WAT will help perform comprehensive watershed scale studies by creating procedures and capabilities that allow integrated modeling using risk analysis. The WAT will produce more consistent results by improving coordination and communication across Project Delivery Teams (PDT). Management would benefit by being able to track project status and display results during public and project status meetings.

This paper will discuss the development, functionality, capabilities, benefits, requirements and application of the WAT to water resources studies.

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) and its partners and stakeholders conduct watershed and water resources management studies. These studies begin with the definition of the existing conditions and continue with analyses of various alternatives. Typically, the studies address flood damage reduction and/or ecosystem restoration needs and often require hydrologic/hydraulic, economic, environmental, and social impact analyses. These studies can be performed by one office but are often performed by many disparate offices. Thus, coordination, file/data sharing, logistics, reporting of modeling results, and status reporting are often a problem.

The Corps' Hydrologic Engineering Center (HEC) is developing the Watershed Analysis Tool (HEC-WAT or the WAT) to give project delivery teams (PDT's) the ability to perform coordinated and efficient modeling and alternative analyses. It will streamline and integrate the models commonly applied for watershed and water resources studies. The WAT is an interface which will use software commonly applied by the studies' multi-disciplinary team.

OBJECTIVES

The primary objective of the WAT is to perform coordinated and comprehensive watershed and water resources management studies. The WAT will streamline the analytical process and enhance coordination and communication across PDT's while producing more consistent results, and shared displays. It will assist with the definition of alternatives, provide for data sharing and model interfacing, and allow for the viewing and evaluation results using risk analysis.

The WAT will encourage a team approach by providing the PDT with a vehicle to develop their models in a closely coordinated manner, track progress of other models, and automatically retrieve results from previous model runs. Management would also benefit by being able to track project status through each modeling component and being able to display results during public and project status meetings. The WAT design is meant to create a powerful and yet intuitive tool.

A graphical user interface (GUI) will allow data and results sharing, common schematic assembly, alternative definition and representation, model setup, editing and implementation, and direct data and results visualization. It is being designed as the umbrella interface for the HEC NexGen suite of software; HEC-SSP, HEC-HMS, HEC-RAS, HEC-ResSim, HEC-FDA, HEC-FIA and HEC-EFM. However, as the WAT matures, links to other models will be incorporated.

DESIGN

In the typical software development process, HEC would write a design document which provides the look and functionality of the software's graphical user interface (GUI) as well direct the development of its compute engine. In the case of the WAT, HEC is not developing another compute engine but rather a tool that will use existing software and their compute engines in a coordinated fashion. HEC is not attempting to replace existing software but rather build an interface that allows the unique pieces of software to work together.

In order for the pieces of software to work together and interact with the WAT, a concept of "plug-ins" was employed. Most of the individual programs have different ways to store and name their files. The plug-ins allow the unique pieces of software to read and write their configurations, plans, or alternatives back and forth to the WAT interface. This interaction includes data and results. By using plug-ins, the amount of re-engineering of the individual pieces of software is kept to a minimum. As other pieces of software are incorporated into the WAT, they will be able to use the same plug-in concept. The plug-in concept will be documented with the intent being that if someone wants to include non-Corps software with the WAT, the owner of the software will be able to create the appropriate plug-in for their software.

In addition to the GUI and compute engine, the typical design document would also address file menus, data structure; file sharing, input and output requirements, and user help. HEC already developed the Corps Water Management System (CWMS) which incorporates these items, but the design of the WAT and it are still quite different. CWMS is built for real-time water management operations while the WAT is directed at water resources or planning type studies. Therefore, because the design process for a coordinated watershed/planning tool is essentially

unprecedented, HEC has not been completely successful in writing a design document that comprehensively captures the WAT. The design document HEC wrote is useful, but does not address every nuance. Therefore, HEC and its contractor, Resource Management Associates, embarked on another development strategy that to date has been quite successful.

The WAT team, consisting of engineers and software developers from both HEC and RMA, has initiated a design build approach for product development. During the initial stages of development, the team conducted several detailed design meetings to discuss immediate and long-term goals and while the existing design document was used extensively during these meetings it still did not address all the needs of the WAT. Acting on the goals, initial development began. To demonstrate and discuss progress, problems, and then to develop solutions, the team meets once every two weeks. Detailed design meeting minutes including design decisions are documented and then placed on the team's Groove share site for further discussion and review. The regular meetings allow the team to stay focused on current development needs, not travel too far down a path that won't work, and compels them to meet assigned targets. The regular meetings also allow for a diverse exchange of ideas which allows the WAT development team to take advantage of many varied experiences.

USER INTERFACE

The WAT GUI is designed to allow the PDT to easily generate the study framework. The GUI, shown in Figure 1, will be the tool used to develop a spatially correct representation of the study area and alternatives. Access to the HEC-WAT design tools will be through menus or tool buttons included with the GUI.

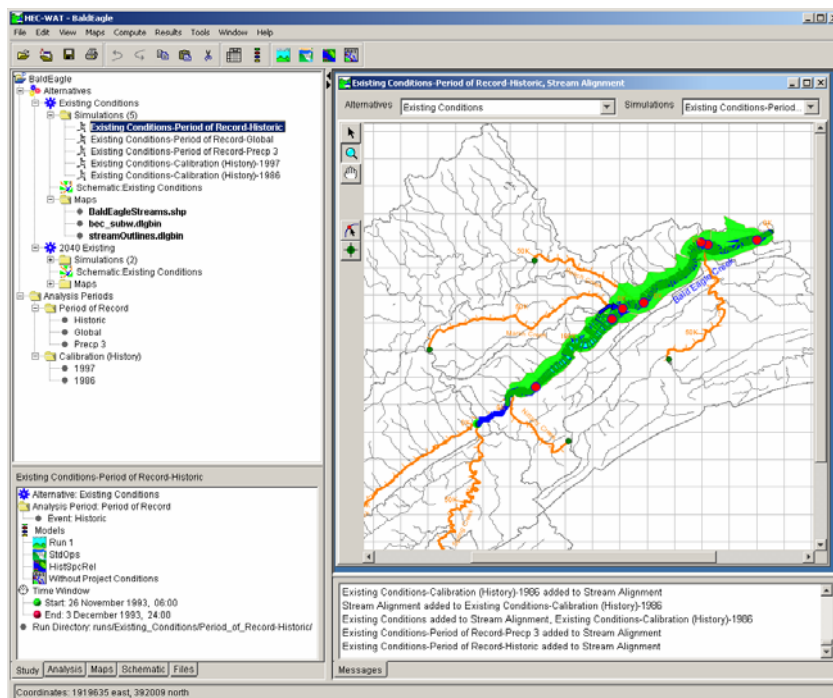


Figure 1 Common WAT Schematic

To begin a study, the PDT would define the common watershed schematic, usually the existing conditions, to be used by each of the modeling teams. The study area may include an entire watershed or only a small section of the basin. The PDT could include existing background layers to visually represent the extent of the watershed. The WAT interface will provide tools to enter these layers.

Also included with the common schematic are the stream alignment and common computation points (CCP). The stream alignment is a representation of the stream as it travels through the watershed. It will generate a consistency between models and study alternatives. CCP's are locations where one model transfers data to another model or a location where results are needed for model development or alternative analysis. Using the capabilities or tools available through the GUI, the stream centerline and CCP's can be drawn or imported in the WAT.

The watershed area, stream alignment, CCP's and flood damage reduction or ecosystem restoration measures can be used across multiple alternatives. If a change is made to one alternative that change will be made across all the alternatives it is associated with.

ALTERNATIVE DEVELOPMENT AND DEFINITION

An issue at the start of any project study is the definition, study extent, and representation of the alternatives to be evaluated. The WAT will help the PDT define alternatives through schematic representations, model identification and compute sequencing, and tabular formats. The watershed extents, the stream alignment, common computation points, and the collection of flood damage reduction or ecosystem restoration measures define the alternative.

To represent alternatives, the PDT will add the existing flood control and ecosystem restoration measures on the common schematic. These measures will be associated with the stream alignment and will be drawn with the available drawing tools. The PDT will identify, name, and represent the alternatives with copying techniques and the drawing tools found in the WAT. The benefit of the WAT is that each of the modeling teams will be able to use the identical schematic to perform their modeling. Naming will be consistent across all models.

While the schematic representation of the alternative is being built, the Alternative and Simulation Manager is being constructed (Figure 2). The manager will list the alternatives, the models, and the analysis periods. It is used to state what data sets need to be developed for each model for each alternative/analysis period/event. Analysis periods include historic events for calibration and study of actual impacts, period-of-record analysis, and probabilistic analysis for planning studies. The PDT will have access to the Manager to document their modeling, check on the status of the other models, and locate the appropriate data for their models. Project Managers could use the table for a quick review on the status of the modeling teams. The Manager provides a concise summary, identifying the location of the data, alternative files, and the developer of all alternatives.

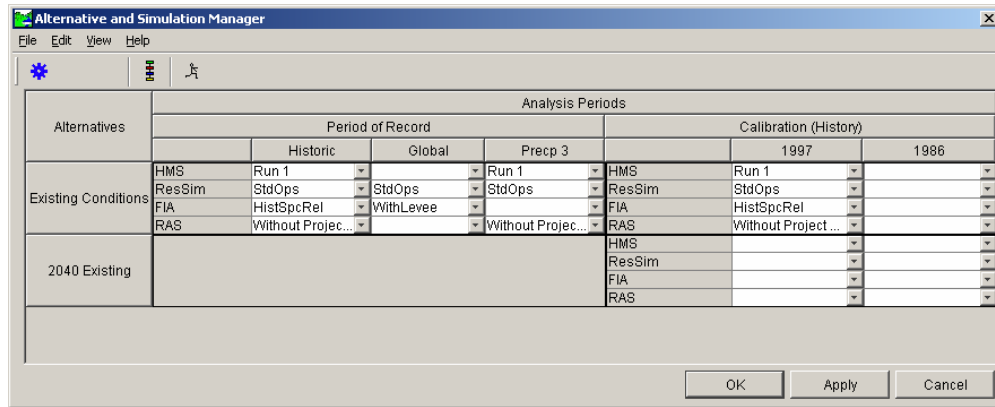


Figure 2 WAT Alternative and Simulation Manager

DATA MANAGEMENT AND ANALYSIS

A large amount and variety of data and information will be used in a typical WAT study. This data is organized so that it is located together in an easily identifiable directory structure. The information is organized so that individual modeling data can be identified and isolated, if necessary. It is also anticipated that individual models will be developed separately from the WAT and the models and their associated data will need to be brought into the WAT. In addition, the WAT's data management structure will allow individual models built within the WAT to be copied from the WAT and used in other studies and environments. The WAT also allows the entire WAT directory structure to be copied to another computer system, and allows for the potential future use of the data in a client-server mode.

A project directory, which is typically named according to its geographic location, will contain separate directories for each of the individual models that are used in that project, as well as a "Common" directory, a "Maps" directory, and a "WAT" directory. The modeling directories will be named according to the model, such as "HEC-RAS" or "HEC-ResSim". The directories and their respective subdirectories will contain all the data and information necessary for that model, except for what is located in the Common and Maps directories. The "Common" directory will contain data files that one or more individual models share. The "Maps" directory will contain background maps and images in various formats. Maps may or may not be shared by individual modeling programs. The WAT will use the Data Storage System (HEC-DSS) for the time series data that can be shared by the models. Users will be encouraged to copy input time series data and observed data to this file to preserve the integrity of having the data in one location, and for the ease of comparison of results.

GIS data sets will be located either in the Common directory, Maps directory, or in an individual model directory, depending on what that data is and how it is used. For example, a background map used by RAS but could be used by other models will be stored in the Maps directory.

Time series icons can be included with the WAT schematic. Once identified, the data associated with that icon can be viewed through plots and tables. By selecting various alternatives from the Manager, then selecting an icon, the user can display a plot or table of the data for the selected

alternatives at that location. Through HEC-DSSVue, anomalies in the data and breaks in the data record can easily be identified and the time window of interest defined.

MODEL INTERFACING

One of the strengths of the WAT is its ability to share model results (Figure 3). HEC envisions that, someday, many programs will be made available through the WAT. However, because it currently is in an elementary state, HEC is only including the software it knows best, its own. As

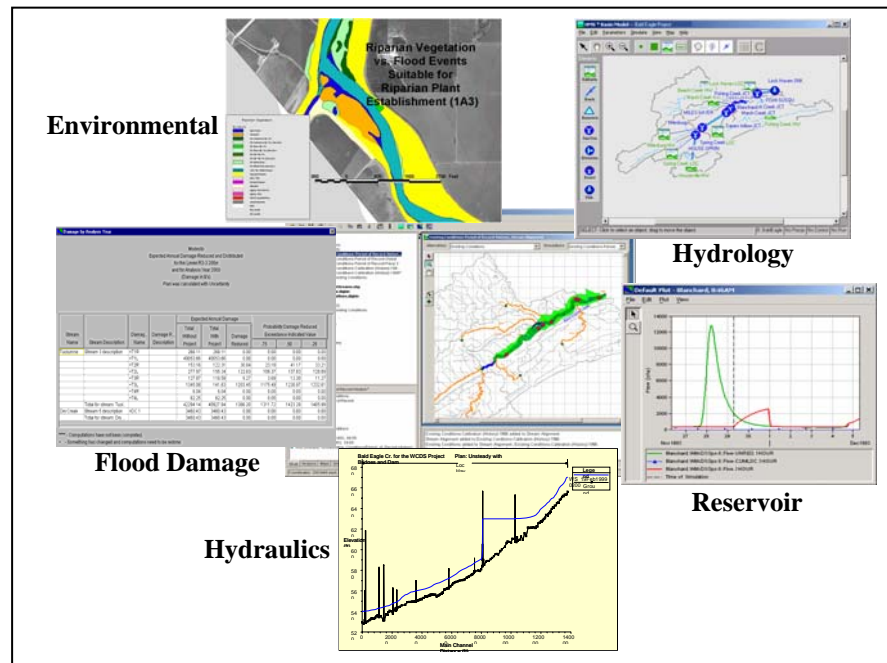


Figure 3 Model Integration in the WAT

the WAT becomes more robust, additional pieces of software will be included through the plug-in concept discussed earlier in this paper. When the Beta version of the software is ready for release, it will include the HEC NexGen Suite: Statistical Software Package (HEC-SSP); Hydrologic Modeling System (HEC-HMS); Reservoir Simulation (HEC-ResSim); River Analysis Systems (HEC-RAS); Flood Damage Reduction Analysis (HEC-FDA & HEC-FIA); and the Ecosystem Functions Model (HEC-EFM). The WAT will define a model compute sequence for these models. This sequence is the order in which programs can be run within the WAT. For example, HEC-HMS may need to generate flows used by HEC-ResSim and the reservoir output is then used as input to HEC-RAS.

Model icons will be provided with a tool bar so the modeling teams will be able to access their respective programs. They will use the common schematic to begin to populate their models with physical data specific to their model and then identify their computation locations. Additional data can be entered and edited and the modeler will be able to review results of their model just as if it were an independent program. The hydrologic team may start by using SSP to create flow frequency relationships at given gage sites using the procedures outlined in Bulletin 17B and Corps guidance. They could use the SSP to perform regional and coincident frequency

analyses as well. Next, the hydrology team would use the schematic and its primary inputs, precipitation in the form of rainfall and snow and surface conditions, to perform the rainfall runoff calculations. The HMS results/files necessary for the other programs would then be saved back to the WAT. The reservoir modelers would then develop their reservoir simulation files using the schematic, the results from HMS, and their own unique input parameters which would be returned to the WAT. The river analysis team could then use the schematic, the HMS or ResSim results, and their unique input parameters to create the watershed's steady or unsteady flow RAS model. The flood damage models (HEC-FDA and HEC-FIA) would then use the schematic, the results from any of the other models, and economic relationships to compute the flood damage whether they are event or probabilistic damages. Finally, the EFM could use the schematic, its own hydrologic vs. biologic relationships, and the results from the RAS and GeoRAS modeling to assist in developing planning alternatives for ecosystem restoration projects. It is envisioned that each of the programs, in addition to providing its normal results, will read and write selected data so the connectivity between the models is made more efficient.

In the future, it is anticipated that two-dimensional modeling will be incorporated into the WAT. For example, in areas where two-dimensional hydraulics may be necessary such as at a bridge crossing or an ecosystem restoration site, the ADH software could be used. An HEC-RAS model would still be developed and used for the watershed study, but at the bridge crossing, the RAS results could define the starting conditions for the localized ADH modeling.

Once all the models for a given alternative are built and their results documented within the WAT Manager, the WAT will make it possible to edit one model and then rerun the entire coordinated string of models in a synchronized fashion. Because of the connectivity between the models, the pertinent data will be passed along until all models have been recomputed.

GIS software will also be used for developing base model data and for visualizing model results. GeoRAS and GeoHMS will be available through the WAT but because of their proprietary status, their connectivity will not be as tightly tied to the WAT. Modeling icons will be available to access these programs but they will not be fully incorporated into the WAT.

ALTERNATIVE ANALYSIS AND REPORTING

After the computations are completed and the alternative(s) selected, alternative results can be viewed and compared directly from the schematic. Any hydrologic object or element (computation points, reservoirs, river reaches, impact areas, storage areas etc.) can be selected on the schematic and a list of tabular or graphical output will be available (Figure 4). Selecting the table or graphic of choice, the WAT will then find that output from appropriate model and display it on the screen. The WAT will also allow the alternative results to be viewed from the individual models. By selecting the proper model icon, the user will be able to view the modeling results from the individual model in the model's traditional process.

STATUS AND FUTURE CONSIDERATIONS

A peer review using the alpha version of the WAT was deemed necessary because the WAT will have widespread use across the Corps for watershed and planning type studies, the members of

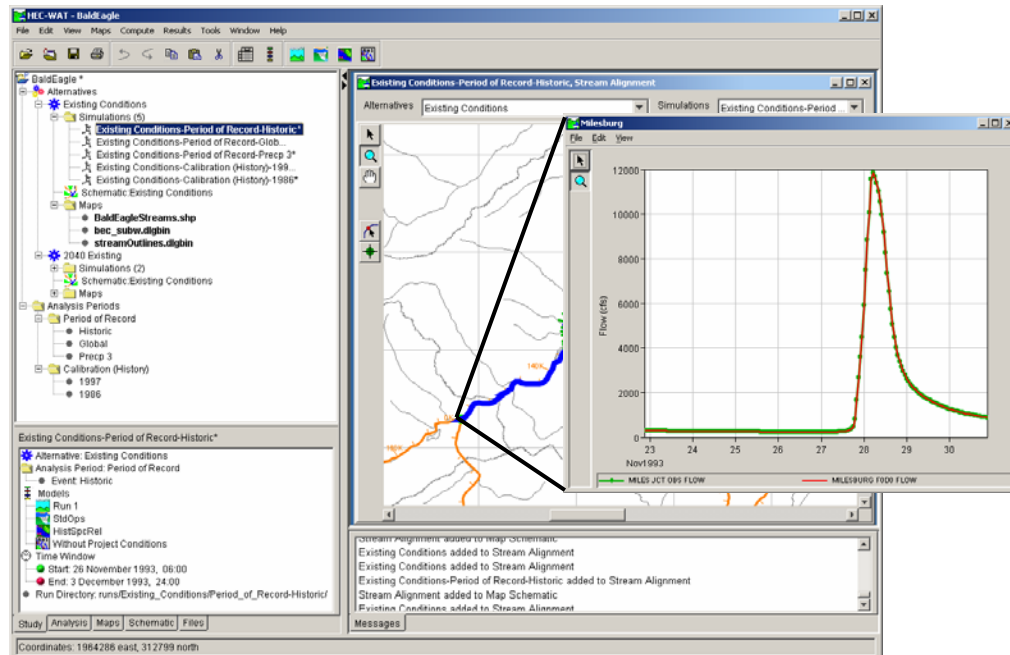


Figure 4 Visualization of Results

the WAT team are from HEC, and it is an attempt to gather other ideas. Members of other Corps offices will be invited to participate in the peer review. Comments and recommendations from the peer review, along with additions to the WAT that have already been identified will be addressed in the FY06. FY06 additions to the WAT include the incorporation of several new pieces of software: HEC-SSP, HEC-FDA, and HEC-EFM.

Following the incorporation of the new pieces of software, addressing the peer review comments, and cleaning up alpha version issues, HEC expects to release a Beta version of the WAT in September 2006. HEC is requesting example watersheds and watershed studies for the development and testing of the Beta version. The Beta version will then be tested by other offices that have expressed interest in the software. Before HEC can release the Beta version, however, HEC needs to provide a User's Manual. Later, an Applications Guide will also be written. These documents will fully describe the capabilities within the WAT, how to use the WAT to improve the coordination of watershed and water resources studies, any limitations of the WAT or the individual pieces of software within WAT, and provide easy to follow examples to guide its users. According to the current schedule, an official release will be made in September 2007. When available, the software will be posted on our Website www.hec.usace.army.mil and notification of its existence would be delivered through e-mail, Corps' publications and conferences. Once the WAT is available, training (through the Corps' PROSPECT training program) and support would also be provided.

HEC has introduced the WAT on several occasions (classes and conferences) and after each the response has been very positive. In most cases, the interested parties want the software today. HEC is doing everything it can to ensure that the WAT meets the user's needs and will be available as soon as possible.